Impact of ICT on GDP per worker: A new approach using confidence in justice system as an instrument.

Evidence from 41 European countries 1996-2010

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Abstract

Although a number of studies have been conducted to understand the impact of ICT on a country's economic output; a complete account for ICT's influence on real GDP per capita has yet to be visualized. This study aims to investigate this topic, by exploring the hypothesis whether ICT has an impact (causal relationship) on real GDP per worker in 41 European countries from 1996-2010. Confidence in the judicial system is taken as an instrument to solve for endogeneity problems. ICT is defined as mobile, broadband and internet penetration per 100 people. We find that confidence in the justice system is a strong instrument for ICT. Therefore, using IV 2sls regression, it is observed that ICT does have a strong positive correlation and causal relationship with GDP per worker, with an elasticity of 0.4 between the variables. In light of the results, the author recommends that economic policies must be tailored to support ICT development in countries.

Key Words:

ICT, GDP per capita, Confidence in Justice System, Instrument, 2SLS, Productivity.

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1. INTRODUCTION

The wealth of a nation is ultimately driven by changes in its productivity; higher productivity results in higher wages, leading to a better living standard (Cardona, Kretschmer, & Strobel, 2013). So what drives productivity? A number of forces are involved in any given economy (Dornbusch, 2001), including ICT (Information Communication Technology). This paper focuses on the role ICT and its effect on real GDP per worker or productivity (Real GDP divided by employed labor). Essentially, if ICT is an important driver of productivity, it highlights the role and necessity ICT investments will have for the economic prosperity and wealth within countries. In this respect, what is ICT's place and how big of an impact does it actually have on productivity?

ICT in itself includes several key technologies which have shaped modern day communication and is defined as the diverse set of resources and technological tools which can be used for communication, storage, management, dissemination and creation of information (Miyata & Hata, 2012). It can have various communication channels such as radio and telephony, whereas telephony includes fixed telephony and mobile channels. (Muwanguzi, 2009). Furthermore, fixed telephony may include fixed broadband and landlines and Mobile communication includes wireless communication. Collectively, the combination of these services has been used in all sectors of the economy including education, health and medicine (Tollmar, Bentley, Moore, & Olwal, 2011).

The motivation for the research is driven by the recent economic policies directed specifically towards ICT. For example, in 2009, the U.S stimulus package worth $7.2 billion was granted for help increase investments in broadband and wireless access (American Recovery and Reinvestment Act) (Caruso, 2009). To elaborate on its effects we can see that even services such as Netflix and Google Fiber have taken on giants such as Comcast, who previously enjoyed a monopoly in several U.S states (Hayes, 2014). The digital age is driven by ICT (Spendlove & Hopper, 2004) – European economic policy has also aimed to capitalize on the recent technological advances, for e.g. the movement for ensuring internet as a basic human right has gained momentum in the past decade (Kui Kinyanjui, 2011). The European commission is of the opinion that download rates of 30Mb/sec should be the norm for all, whereas by 2020, at least half the population should have access to 100Mb/sec internet speed (Zander & Mähönen, 2013; Ballon & Van Heesvelde, 2011).

Furthermore, ICT can be a facilitator for social inclusion. Austin (2007) conducted a survey to assess the role of ICT across the political boundary between Northern Ireland and Republic of Ireland. The study focused specifically on teacher-pupil and pupil-pupil interaction, and found that ICT improved social interaction and the children's perception of each other. Similarly, ICT also plays an important role in the socio economic development of a country. Forzati & Mattsson (2014) find a 10 percent increase in population living within 353 meters of a broad band fiber to the home connection. The area also shows a 0.25% positive change in population after three years and a 0.2% increase in employment after two and a half years. They used a multivariate regression analysis on 290 municipalities in Sweden during 2007-2010.

However, even with such developments, some researchers are of the opinion that less investment in ICT is a better option and that ICT is burdened by diminishing returns (Postholm, 2007).

The fact that ICT may impact productivity at a multitude of levels, from the social or business environment, to the way business is done and how the markets operate with recent reduction in ICT costs (Saltari, Wymer, & Federici, 2013) has sparked a large interest amongst academia. The purpose has been to try to understand the effects ICT may have on production processes, efficiency, output growth etc. (Cardona et al., 2013). The findings on the extent of the impact of ICT on productivity have been at odds and several methods have been employed at different aggregation levels, using different definitions on ICT, and employing different databases (Stevenson, 2011).

Schreyer (2001) suggests that the main reason earlier studies could not find a significant impact of ICT on GDP per capita was due to the ICT capital being too low. Productivity estimates in other studies have shown positive elasticity estimates between ICT and GDP per capita, however, they are not coherent. Loveman (1994) found a negative relationship between the two variables with an elasticity of -0.04. The study was conducted the firm level during 1978-1984 in the U.S. Similarly Stiroh (2002) finds the elasticity between the variables to be -0.071 at the industry level during the time period 1973-1999 in the U.S. Finally Dewan and Kraemer (2000) find a negative relationship and elasticity of -0.013 at the country level in Europe. The time period they selected is 1985-1993.

Although other researchers have found a positive relationship, the most cited paper published in this regard is by Rasiah (2006), who found a positive relationship and elasticity of 0.83. However, this number is disputable, as other researchers have found the elasticity as low as 0.05 (Black and Lynch 2001) and 0.021 (Gilchrist et al. 2001) to a maximum of 0.162 (Madden and Savage 2000 cited in Cardona 2012).

Therefore, in many cases as research points out, the Solow productivity paradox noted by Byrnjolfsson (2000) still holds true today. Solow (cited in Craft 2002) stated that:

“You can see the computer age everywhere but in the productivity statistics”

Brynjolfsson (2000) find that ICT performance depends on complementary organizational investments which lead to improvement in intangible aspects. therefore they are not well captured using traditional macroeconomic approaches, thereby leading to the Solow Paradox.

It is also evident that the productivity measure depends on the method and database used (Cardona 2012). Although a positive relationship between ICT and GDP per capita would help shape policies to support uptake of ICT services in countries, the underlying questions remains: how can we define and how can we construct the empirical analysis given the complexity inherent to this area of research and with the limited datasets available? This includes understanding and developing the right instruments, and to find a sample size large enough with consistent data for the analysis.

The hypothesis to be tested therefore, using a 2SLS specification with confidence in justice system as an instrument, is:

Has ICT had an impact on real GDP per worker in European countries over the period 1996-2010?

This new approach adds novelty to the research and contributes to existing literature. In the specification several control variables namely foreign direct investment (FDI), Openness, OECD dummy, government consumption share, household consumption share, civil liberties, public rights and freedom are added to solve for endogeneity issues for the instrument. The complete regression specification shows that if ICT increases by one percent, GDP per worker increases by 0.408 percent compared to 0.148 percent in case of ordinary least square (OLS) regression. The finding shows that ICT has a positive and significant impact on GDP per worker, but not as high as predicted by Rasiah (2006).

The following sections are organized as follows: Section 2 provides a literature review on the most recent studies conducted in this field of study. A theoretical model is developed in Section 3, which helps identifying the data and variables that must be used for the empirical analysis. Section 4 then defines the data and the methodology used to realize the theoretical model. Section 5 provides results of these estimations. Section 6 conclude the paper and provide policy implications.

2. LITERATURE REVIEW

ICT services have seen a sharp rise in the last decade. Figure 1 shows that the highest percentage of population using fixed broadband services was seen in North America during 1999-2012, followed by Europe and Central Asia. Figure 2 shows that the highest percentage of the population using mobile services was observed in Europe & Central Asia during 1999-2012. The percentage exceeds 100 percent due to ownership of multiple mobiles. For example mobile service subscriptions exceeded total population by 5 percent, and this has been attributed to quasi subscribers i.e. a single user with multiple subscriptions (Annafari & Bohlin, 2014). Therefore, it is evident that number of ICT users has increased drastically worldwide in the past years.

Building on, I turn my focus to the question: how has previous research has enabled us to see ICT and its effects on economic growth (in terms of increase in real GPD per worker).

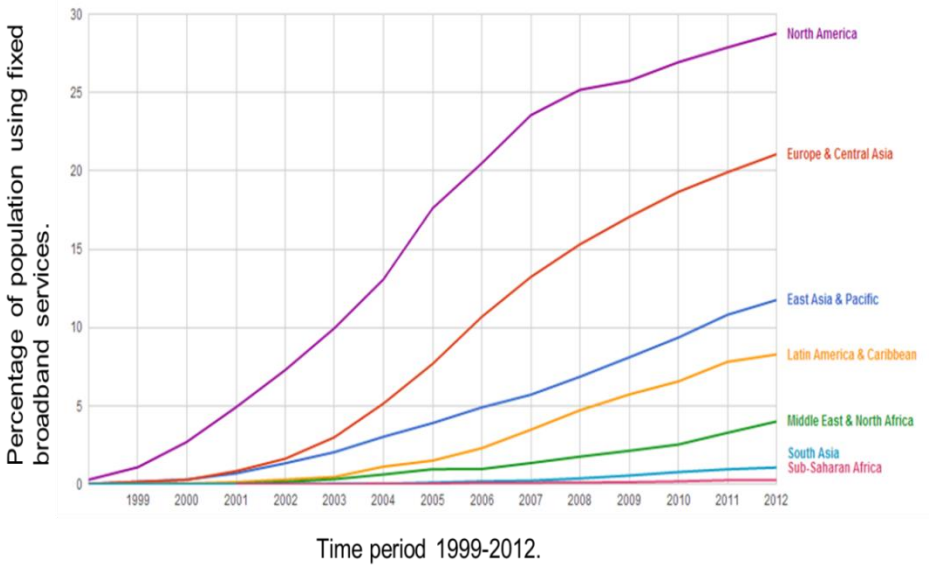

Figure 1 Fixed broadband users per continent.
Source: (World Bank, 2014).

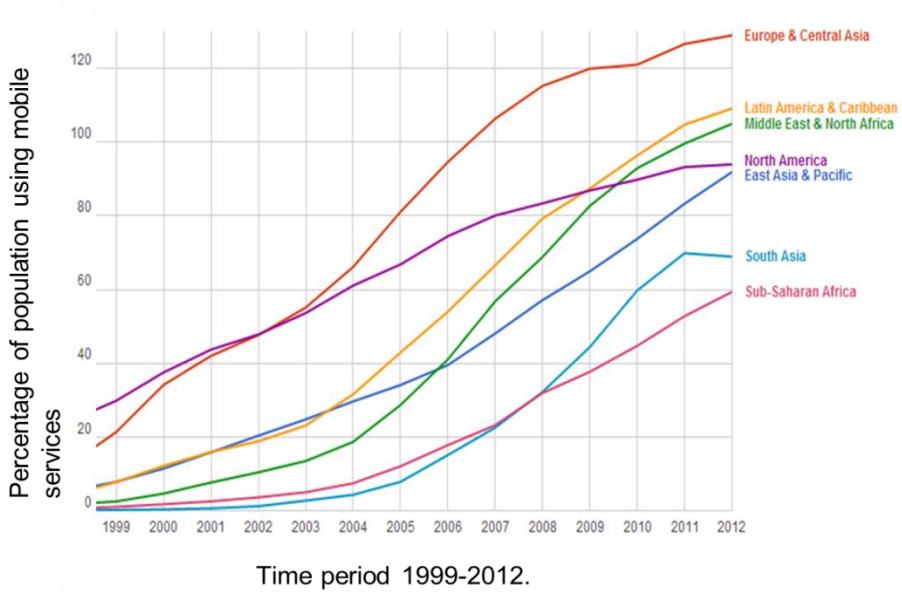

Figure 2 Mobile users per continent.
Source: (World Bank, 2014) .

Jipp (1963), using an OLS regression, find that there is a positive relationship between telephone mainlines and GDP per capita in the U.S. Similarly, Norton (1992), using Kormedi/Meguire (1985) regression with additional variable for telecommunication infrastructure, found that telecommunications lower transaction costs which would otherwise impede economic growth. The study used a cross section of 30 countries during the years 1955-65 and found a strong correlation between telecommunication and economic growth. Cronin, Colleran, Herbert, & Lewitzky (1993) find bi directional causality at state level between telecom investments and the GDP in the U.S. during the time period 1963-1991 using the Granger and Modified Sim Test. More studies built onto the initial findings by Cronin et al (1993), using multiple regression models and adding more variables; for example Dholakia & Harlam (1994) included variables such as human capital and infrastructure and found a positive co relation between telecom infrastructure and real GDP per capita. They find that even when alternative operationalizations of economic development e.g. per capita income and average annual pay are used, the result holds. The study was conducted on 50 states within the U.S. in the 1990's. Other researchers included teledensity (defined as number of telephone connections for every hundred individuals within a certain area) as a variable and found out that although ICT has an impact on real GDP per capita, teledensity did not play a vital role (Mbarika, Kah, Musa, Meso, & Warren, 2003). They used a linear regression model for 119 countries.

Datta & Agarwal (2004) use a dynamic panel data method which corrects for omitted variables bias of single equation cross-section regression for a dataset of 22 OECD countries to investigate whether telecommunication infrastructure has an impact on GDP per capita. They find a strong positive correlation. Similarly, Yoo (2001), employing the use of OLS regression on a data set of 56 developing countries worldwide found that, indeed telecommunication infrastructure plays an important role in a country's economic progress or real GDP per capita.

The bulk of studies conducted aimed to understand the causality (either one way or bi directional) between ICT and real GDP per capita. GDP per capita also impacts ICT. Increase in economic activity has been seen as a precursor for telecom growth in previous studies (Hardy, 1980). Hardy (1980) conducted a study on 60 developing and developed countries, using path lagged and cross lagged correlation techniques and found strong evidence that telephones contribute to economic development and telephone growth is related to advances in knowledge and economies of scale to income growth. Rasiah (2006), using OLS regression for a data set of 49 countries worldwide during 1995-2000 report a positive and strong relationship between both GDP per capita and ICT and ICT expenditure and GDP per capita.. He also shows that real GDP growth precedes growth within ICT and that, based on ICT, real GDP per capita will rise over time. Similarly Wolde-Rufael (2007) uses a modified approach of a granger causality test used by Toda and Yamamoto and find that ICT and GDP per capita have strong correlation and bi directional causality. The study was conducted in the U.S. for the time period 1947-1999. Telecommunication infrastructure is defined as the telephone lines per 100 people, or in certain cases mobile and internet lines 100 people.

Cieślik & Kaniewska (2004) conduct a causality analysis for Poland in 1990's by including income, employment, educational level, telephone infrastructure and also road infrastructure as

an added variable. They use OLS regression for pooled data approach and fixed effects for panel data approach to test for granger causality. In this case they also find that these factors show a strong correlation towards real GDP per capita in Poland. They report bi- directional causality from ICT infrastructure to real GDP per capita. Lam & Shiu (2010) measure causality between teledensity and GDP per capita for 105 countries from 1980-2006 using Dynamic panel data model. They find that bidirectional causality for high income groups and unidirectional causality from ICT to GDP per capita for other income groups namely in Africa and Americas. Table 1 provides a summary of the literature review.

Basu & Fernald (2000) said regarding ICT and its impact on real GDP per capita, considering it has an impact on several fronts:

"The suspect's fingerprints are all over the crime scene".

So, it can be seen that ICT has been viewed from various angles, by including different variables and methods which yield different results in its relationship to productivity.

Table 1 Summary of Literature Review

Study	Sample	Method/ICT definition	Key Findings
(Jipp, 1963)	Correlation between telephone mainlines and real GDP in the U.S. during 1950-1960.	OLS regression. ICT defined as telephone main lines.	Positive relationship between tele phone mainline and GDP per capita observed.
(Hardy, 1980)	Study conducted on 60 developing and developed countries.	Path lagged and cross lagged correlation techniques. ICT defined as telephone main lines.	Evidence that telephones contribute to economic development and telephone growth is related to advances in knowledge and economies of scale to income growth.
(Norton, 1992)	30 countries during 1955-65.	Kormedi/Meguire (1985) regression with additional variable for telecommunication infrastructure. Telecommunication investment used as a measure for ICT.	Telecommunications lower transaction costs which otherwise impede economic growth. Correlation between telecommunication and economic growth.
(Cronin et al., 1993)	Study conducted in the U.S. for time period 1963-1991.	Granger and Modified Sims Test. Telecommunication investment used as a measure for ICT.	Bidirectional causality between telecom investments and real GDP found.
(Dholakia & Harlam, 1994)	Conducted on 50 states within U.S. in the 1990's.	OLS regression. ICT measured through teledensity.	Positive relationship between ICT and economic development. Builds on Cronins (1993) result that even when alternative operationalizations of economic development e.g. per capita income and average annual pay are used, the results hold.
Loveman (1994)	The study was conducted the firm level during 1978-1984 in the U.S	OLS regression, teledensity used a measure for ICT.	Negative relationship between GDP per capita and ICT with an elasticity of -0.04.
Dewan & Kramer (2000)	The time period they selected is 1985-1993. Data includes 32 European countries.	OLS regression. Information Technology used as a measure of ICT.	Negative relationship between GDP per capita and ICT; Elasticity of -0.013 at the country level.
Black & Lynch (2001)	Time period of 1987-1993. Survey conducted in U.S. encompassing 3000 firms.	Using an augmented Cobb-Douglas production function. Information Technology used as a measure of ICT.	Weak positive relationship between IT and GDP per capita observed (Elasticity of 0.05).
Gilchrist (2001)	Data from fortune 1000 manufacturing firms from 1986-1993	Instrumental analysis using lagged variables. PC usage used as a measure of ICT.	Very weak positive relationship between PC usage and GDP per capita (Elasticity of 0.021).

Stiroh (2002)	Study conducted during the time period 1973-1999 in the U.S.	OLS regression, teledensity used as a measure for ICT.	Negative elasticity of -0.071 between GDP per capita and ICT at the industry level.
Madden and Savage (2000)	A sample of 43 countries used, of which 16 are developed countries.	The Mankiw et al. (MRW, 1992) model is used by including telecommunications capital in the aggregate Cobb-Douglas production function. Telecommunication infrastructure is parameter within ICT tested.	A positive cross-country relationship between telecommunications capital and economic growth.
(Yoo, 2001)	Impact of ICT on real GDP through telecom infrastructure in 56 developing countries.	OLS regression. Telecommunication infrastructure used as a measure for ICT.	Telecommunication infrastructure plays an important role in a country's economic progress or real GDP per capita.
(Mbarika et al., 2003)	Impact of ICT on real GDP per capita, data employed linear regression with 119 countries.	OLS regression. Teledensity used as a measure for ICT.	Although ICT had an impact on real GDP per capita, teledensity played a vital and important role.
(Datta & Agarwal, 2004)	Conducted on 22 OECD countries	Dynamic panel data method which corrects for omitted variables bias of single equation cross-section regression. Teledensity used as a measure for ICT.	Significant and positive correlation and uni directional causality from ICT to real GDP, after controlling for government consumption, population growth, total investment and degree of openness.
(Rasiah, 2006)	49 countries worldwide during the period 1995-2000.	OLS regression. Teledensity used as a measure for ICT.	Strong positive relationship between ICT and GDP per capita & ICT expenditure and GDP per capita (elasticity of 0.8 observed between the variables).
(Cieślik & Kaniewska, 2004)	Causality analysis in Poland in 1990's by including income, employment, educational level amongst other factors.	OLS regression for pooled data approach and Fixed effects for panel data approach to test for granger causality. Teledensity used as a measure for ICT.	Strong correlation of added factors towards real GDP per capita in Poland. Bi directional causality exists.
(Wolde-Rufael, 2007)	Understanding causal relationship between ICT and GDP per capita in U.S during 1947-1999.	Modified Wald Test MWALD. Teledensity used as a measure for ICT.	Strong bi directional causal relationship between ICT and GDP per capita.
(Lam & Shiu, 2010)	Causality between teledensity and GDP per capita for 105 countries from 1980-2006.	Dynamic panel data model to investigate causality using Granger Causality and Wald Tests. Teledensity used as a measure for ICT.	Bidirectional causality for high income groups and unidirectional causality for other income groups namely in Africa and Americas.

3. THEORETICAL MODEL

I proceed to develop a theoretical model which will be the foundation for the selection of estimation methodology, the data, and analyzing the results.

ICT may be considered an input to production. For this purpose, the Solow model can be used. The basic production function (in Cobb-Douglas) form can be expressed as (Woolridge 2013):

$$Y = K^{\alpha}(AL)^{1-\alpha} \quad \text{Where } 0 < \alpha < 1 \tag{1}$$

K is capital, L is labor, Y is the output and A is the level of labor augmenting technology and α is the output elasticity of the capital. The capital accumulation equation is necessary to derive the steady state equation for the model. This is given as:

$$\dot{K} = sY - dK \tag{2}$$

Where s is the savings share and d is the depreciation of capital stock. $\dot{K}$ is the capital stock changing with time, and is equal to the amount of investment (through savings) minus the depreciation of the capital.

Equation (2) can be rewritten into capital and output per effective unit of labor as:

$$\dot{k} = sy - (d+g+n)\,k \tag{3}$$

Where g and n denote growth rate of technology and workers, respectively and,

$$k \equiv \frac{K}{AL} \qquad y \equiv \frac{Y}{AL}.$$

This shows that the change in capital per effective unit of labor is positively impacted by the investment per effective unit of labor and negatively influenced by the depreciation per effective unit of labor (Woolridge 2013). For the steady state condition, *k* reached the value *k**, and at this point $\dot{k}$ will equal zero,

$$\dot{k} = 0 \Leftrightarrow sy = (d+g+n)k \tag{4}$$

Solving for the steady state capital stock per effective unit of labor gives us:

$$k^* = \left(\frac{s}{d+g+n}\right)^{\frac{1}{1-\alpha}} \tag{5}$$

And

$$y^* = \left(\frac{s}{d+g+n}\right)^{\frac{\alpha}{1-\alpha}} \tag{6}$$

The output per worker at steady state condition can be derived as:

$$\tilde{y} = A\left(\frac{s}{d+g+n}\right)^{\frac{\alpha}{1-\alpha}}, \qquad \tilde{\boldsymbol{y}} \equiv \frac{\boldsymbol{Y}}{\boldsymbol{L}} \tag{7}$$

It is my hypothesis that the labor productivity is impacted by ICT (I) penetration and human capital (H). So we can write this as:

$$A = e^{\delta_1 I + \delta_2 H} \tag{8}$$

Where δ_1 and δ_2 are greater than zero.

δ_1 Shows the impact ICT penetration has on the labor productivity, whereas δ_2 provides a measure for the impact of human capital.

Combining (7) and (8)

$$\tilde{y} = e^{\delta_1 I + \delta_2 H}\left(\frac{s}{d+g+n}\right)^{\frac{\alpha}{1-\alpha}} \tag{9}$$

Log of (9) gives:

$$\ln \tilde{y} = \left(\frac{\alpha}{1-\alpha}\right)\ln s + \delta_1 I + \delta_2 H - \left(\frac{\alpha}{1-\alpha}\right)\ln(d+g+n) \tag{10}$$

This equation provides the necessary relationship which I will use to conduct my analysis. It shows that savings, ICT penetration and human capital positively impact GDP per work while effective depreciation has a negative effect on it.

4. EMPIRICAL STRATEGY AND DATA

4.1. ESTIMATION METHODOLOGY

Theoretically (9) can be written as:

$$\ln \tilde{y}_{i,t} = \beta_0 + \beta_1 \ln s_{i,t} + \beta_2 I_{i,t} + \beta_3 H_{i,t} + \beta_4 \ln(d + g_{i,t} + n_{i,t}) + Q'_{i,t}\beta_5 + \varepsilon_{i,t} \quad (11)$$

We can expect that in (11) coefficients β_1, β_2 and β_3 have positive values, as they are related to ICT penetration, human capital and investment (saving) while β_4 corresponds to the coefficient for effective depreciation. Q' is used to denote the control variables necessary for the estimation whereas *i* and *t* represent country and time respectively.

The first step is to assess whether a simple one stage ordinary least square estimation (OLS) can be used to test the hypothesis: whether ICT penetration has an impact on GDP per worker.

However, I suspect that ICT is correlated with the error term in (11). This means that ICT is correlated with some other unobserved variable that affects GDP per capita, therefore all estimates will be biased. This can be solved by using a 2SLS regression specification and finding a variable (instrument) which, according to Wooldridge (2013), must fulfill two conditions: (i) it should be closely related to the explanatory variable – in this case $I_{i,t}$ and (ii) it should not have correlation with the error term $\varepsilon_{i,t}$ which means it is exogenous in equation (11).

This method involves two-stages with a least square regression in each step (Carter. Hill, 2008; Davidson & Mackinnon, 2008). We can write $I_{i,t}$ as:

$$I_{i,t} = \gamma_0 + \gamma_1 s_{i,t} + \gamma_2 Z_{i,t} + \gamma_3 H_{i,t} + \gamma_4 \ln(d + g_{i,t} + n_{i,t}) + Q'_{i,t}\gamma_5 + \varepsilon_{i,t} \quad (12)$$

(12) Contains the endogenous variable on the left hand side, while the remaining exogenous variables are on the right hand side. Equation (13) is then estimated in the second stage by using predicted value of $I_{i,t}$ based on the instrument Z, and can be written as $\hat{I}_{i,t}$. This gives:

$$\ln y_{i,t} = \beta_0 + \beta_1 \ln s_{i,t} + \beta_2 \ln \hat{I}_{i,t} + \beta_3 \ln H_{i,t} + \beta_4 \ln(d + g_{i.t} + n_{i,t}) + Q'_{i,t}\beta_5 + \hat{\varepsilon}_{i,t} \quad (13)$$

4.2. SELECTION OF THE INSTRUMENT AND ITS RELEVANCE

A thorough search was conducted to find other research papers which have used instrumental variables to determine the relationship between GDP per capita and ICT. Only one paper written by Gilchrist (2001) was found to have used IV analysis. They used lagged variables as instruments, and defined ICT through PC usage in manufacturing firms. They find a very weak elasticity between PC usage and GDP per capita, which can be due to a weak instrument and a small data set comprising 7 years and only a segment of ICT.

The instrument we have selected is 'Confidence in the Justice System' for ICT penetration with the intuition that it will be a stronger and better instrument. This is due to a number of factors,

primarily because of the recent impact of a countries judiciary system and the confidence people have in using services (e.g. Twitter, Facebook – which form part of ICT through use of mobile services or broadband). Vu (2008) shows that one of the variables that impacts ICT (albeit ICT capital in their case), is the judicial system of a country, amongst other variables such as education, status as being a developed country and infrastructure. Not enough research has been done on this particular factor, and I aim to show its relevance to ICT, which is the first demand on the instrument (Woolridge 2013).

In recent times ICT has been the corner stone of communication, to the extent that its pervasive abilities have allowed oppressed people in developing countries to raise their voice. The example of Egypt is worth mentioning, where the uprising was brought by social media, which had been available due to ICT penetration throughout the country. However, efforts by the government regimes to restrict the use of this technology, reduced the usage in the country, and also gave an indication to investors to reduce their ICT coverage and operations in the country. The judicial system is the key institution which can enforce regulations for human rights - it is relevant to mention internet/ICT have been motioned forward to be accepted as a basic human right (Kui Kinyanjui, 2011). They ensure that governments do not impose unnecessary restrictions, such as in the case of Egypt. The measure of the system can be estimated via the people's confidence of the system.

Another recent example includes the banning of YouTube (social media) in Pakistan. This has been a subject of controversy; political motivations have led to banning of services which are essential for the nation (Masood, 2012). The key institution to be able to solve this issue is the judiciary, which has been scrutinized for its inefficiency in this regard. The message sent by restrictions on the most basic of services hindered the launch of 3G and 4G services in the country (pertaining to the mobile portion of ICT), and caused a lower than expected increase in service lines within the past years (Anwar Khan, 2010).

Similarly, in Europe, the recent cyber surveillance by the National Security Agency (NSA), Unites States, has led to an outcry amongst the people. In Germany, people and investors alike see this as a cause of concern, and a failure of the judiciary to protect the rights of their citizens. Many in governmental organizations have opted to use type writers as the secure means of communication, which cannot be intercepted by foreign agencies (Luiijf, Besseling, & de Graaf, 2013). This leads to a lower confidence in the judicial system which may be able to rectify the situation and in turn a lower value in ICT penetration.

In Turkey, riots sparked by the banning of Twitter, motivated politically to prevent footage of government officials engaged in illegal activities, can be seen as another sign of the failure of the judicial system (Arsu & Bilefsky, 2014). The loss of confidence thereof may impact ICT penetration for the country.

Stevenson & Wolfers (2011) analyzed citizen trust in US public institutions (including judicial system) during 2006-2010 and the impact of firm entry rates. They find that 10% increase in share of population trusting judiciaries is associated with 0.38 percentage point increase in firm entry rate. Lucidi (2014) has recently shown that ICT penetration impacts disposition time (time taken to pass verdict on a case) and backlog ratio in courts. He states that increasing public

budget for in-court ICT tools is associated with a decrease in disposition time by 1% and backlog ratio by 1%. It can be hypothesized that if ICT can impact back log ratio and disposition times in judicial courts, the opposite relationship might also exist i.e. a good judicial system would increase uptake of ICT services.

Therefore, justice in confidence system is a relevant instrument for ICT, and fulfills the first requirement as suggested by Woolridge (2013).

4.3. EXOGENEITY OF THE INSTRUMENT

However, a good judicial system (measured through confidence in justice system in this paper), will also impact real GDP per capita through other channels rather than just ICT, which would lead to the issue of endogeneity. If the instrument is endogenous, it will not satisfy the exogeneity requirement set forth for it to be a valid instrument - that justice in confidence system should impact GDP per capita only via ICT (Wooldridge, 2013). To account for this I try to control for all the other channels explicitly by including a number of additional variables. Once all channels are controlled for which may affect GDP per worker, the instrument will be exogenous. The control variables added and their rationale is provided as follows:

Foreign Direct Investment (FDI): Barkbu, Rahman, & Valdes (2012) show that a properly functioning judicial system is important in determining a country's economic performance in terms of increased incentives to save and invest and stimulate foreign direct investment (FDI). Jappelli, Pagano, & Bianco (2005) show that improving judicial efficiency reduced credit rationing and increased lending from banks. They used panel data at province level for Italy. Similarly firm owners face a reduced risk to invest by an efficient judicial system (Laeven & Woodruff, 2007). Lucidi (2014) tested the economic intuition that efficient judicial systems would incentivize entrepreneurship and increase firm entry in a market and in turn increase FDI. In their case, they use geographical organization of courts, number of judges, in court ICT intensity and number and size of courts as their instruments for their estimation. Their research shows that judicial efficiency and improvement in the system impact economic outcomes primarily via FDI. The control variable they used for FDI is GDP growth and openness. Therefore confidence in justice system will impact GDP per capita through FDI. To solve for the exogeneity in our regression specification, FDI can be included as part of the control variables, as justified through Lucidi's (2014) research. FDI (inwards) as percentage of GDP is taken from World Bank Database (2014).

Openness: Rigobon & Rodrik (2005) show that judiciary has a positive impact on openness (trade/GDP) and that openness impacts GDP per capita, which is another channel how our instrument can impact GDP per capita other than ICT. They use data with two sub samples: colonies vs non-colonies and continents aligned on an East-West versus North-South axis. To cater for this I include the control variable openness.

OECD dummy: It is expected that OECD countries are more developed and have better judicial systems (Pilat, 2003); therefore a higher level of judicial confidence in the system. They also have higher GDP per capita. In my data 25/41 countries are part of OECD, therefore I add OECD dummy as a control variable and expect it to have a positive sign.

Government consumption share: A lower confidence suggests a corrupt system, which may make decisions which can adversely or positively impact GDP per capita (Barkbu et al., 2012). For instance a country such as Pakistan has high corruption in courts. This leads to policies and legislation which are politically biased (Louise Barrington, 2000). An example is the increased military expenses which are authorized through such courts, thereby reducing GDP per capita (Shahbaz, Shabbir, & Butt, 2013; Binningsbø, Loyle, Gates, & Elster, 2012). Therefore, justice in confidence system impacts GDP per worker through politically biased courts and excessive military expenditures. Government consumption share is used as a proxy to cater for its effects and this control variable is expected to be negative in accordance with Barro's (2000) work.

Household consumption share: Judiciary can positively or negatively impact GDP per capita through household consumption share. For example the U.S Supreme Court ordered dissolution of AT&T and T Mobile USA merger deal (Stucke & Grunes, 2012), as a monopoly in the market would impact the common household due to the fact that ICT has various household uses e.g. in cars, telephones and even kitchen appliances (Røpke, Haunstrup Christensen, & Ole Jensen, 2010). The household consumption may also impact GDP per capita as many people work from home and use these services for their businesses (Comor, 2000).

Civil Liberties and Public Rights: Justice System impacts human rights, governance, and property rights. The overarching umbrella for these affected variables is civil liberties. It is seen that judiciary impacts the civil liberties in a society which in turn impact GDP per capita, through for example property rights and increased efficiency in organizations (Lawson & Clark, 2010) .Therefore I use civil liberties as a control variable in my regression specification. Similarly, public rights are decided and ruled in the court of law. Public rights include the right to safety and protection. (Jackson & Bradford, 2009) show that justice impacts the safety of individuals which in turn has an economic impact through GDP per capita. Intuitively one can assume that confidence in justice impacts the crime levels in a country, therefore it is another way how GDP per capita can be affected other than through ICT. This proxy i.e. public right can help solve for this issue. Crimes committed against the public rights of an individual may cause a loss in GDP per capita; (Loya, 2014) shows that a poor judiciary and crime prevention system may lead to workplace harassment or in some cases rapes, which in turn have a long lasting economic impact. Therefore I use public rights in my specification. It must be noted that civil liberties and public rights cannot be treated as substitutes to each other, as their nature is complementary (Fabro & Aixalá, 2012).

Freedom: Justice impacts civil, public, economic and social freedom (Ebrahim, 2013; Fabro & Aixalá, 2012). Justice also impacts democracy in a state, which falls under the scope of political freedom. They state that all of these elements impact GDP per capita e.g. economic freedom may reduce transaction costs and increase GDP per capita, therefore I use Freedom of a country as a proxy in my data to cater for any effects of justice on GDP per capita through political or economic freedom.

4.4. DATA DESCRIPTION AND SOURCES

The data on confidence on justice system is taken from European Values Study (EVS), for 41 countries in Europe, both OECD and non OECD, during the time period 1998-2010. The

answers are rated on a Likert scale from 0 to 3, where 3 is the highest confidence and 0 is the lowest confidence in the country's judicial system. Figure 3 shows linear fitted plots for GDP per capita against ICT, logarithm and Confidence in justice system against ICT, log.

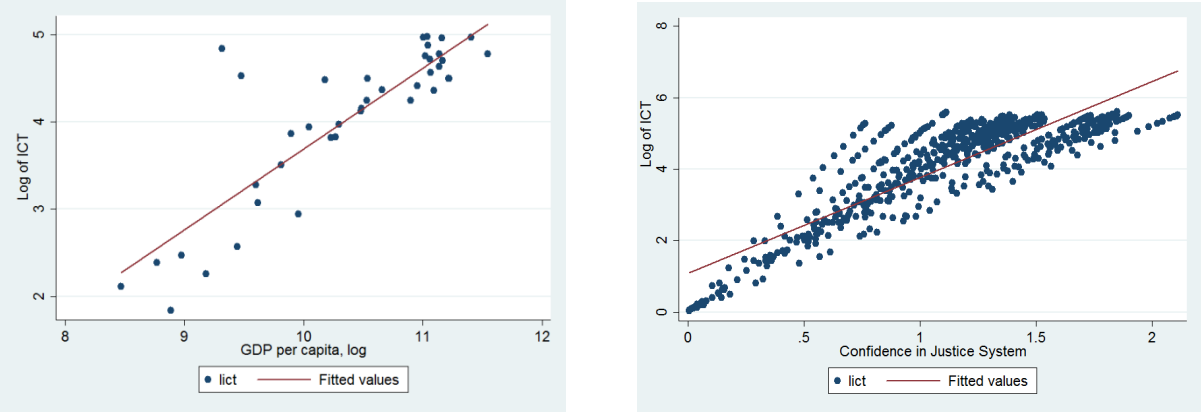

Figure 3 Two way scatter, linear fitted plot GDP per capita vs ICT log and Confidence in justice system vs ICT, log.

The sample size of observations from EVS is n=166503, divided amongst the countries during 1996-2010 and since there are several hundred responses per country per year, I have taken the average for each year, for each country. The output variable or GDP per worker is taken from the Penn World Tables., given as the PPP Converted GDP per worker at 2005 constant prices in (PPP converted GDP is real GDP).

The endogenous variable ICT or I in equation (13) is calculated as sum of Mobile subscribers per 100 people, internet subscriber per 100 people and broadband subscribers per 100 people. This data is collected from World Bank (2014).

The factor $n+g+d$ known as effective depreciation is given by the growth rate of the labor force, growth rate of labor augmenting technology and the depreciation rate for physical capital. I take the depreciation rate as 0.05, based on the average for Europe taken from EU KLEMS (2014). A proxy for 'g' is approximated using long-run annual average growth rate of real GDP per worker taken from World Bank Database (2014). The average labor growth rate is also taken from the same database. The proxy used for saving rate is the investment share of PPP converted GDP Per Capita at 2005 constant prices, taken from Penn World Tables as well. The last factor of importance is the level of education. Education enrollment at tertiary level is taken from World Bank (2014), which serves as a proxy for the human capital *H*. The level of education is important, as can be seen from the literature review, and is assumed that higher educational levels would show a greater GDP per worker. Table 2 provides a list of the variables used and their corresponding definitions and sources.

Table 2 Definition of Variables, and Sources Used.

Variable Name	Definition	Source
GDP per worker, natural logarithm	Log GDP per worker (PPP Converted GDP per worker at 2005 constant prices).	Penn World Tables (2014)
Fixed telephone subscribers	Fixed line telephone subscribers per 100 people.	(World Bank 2014)
Mobile subscribers	Mobile telephone subscribers per 100 people.	(World Bank 2014)
Internet users	Internet users per 100 people.	(World Bank 2014)
ICT, natural logarithm	Log of total ICT penetration per country per 100 people. ICT is the sum of Fixed, Mobile and Internet.	(World Bank 2014)
Justice Confidence, natural logarithm	Confidence in the justice system	European Value Survey (2014)
Investment share, natural logarithm	Log of investment share of PPP converted GDP Per Capita at 2005	Penn World Tables (2014)
Enrollment at tertiary Education, natural logarithm	Log Education enrollment at tertiary level, expressed as a percentage of the total population of the five-year age group following on from secondary school leaving.	World Bank (2014)
Foreign Direct Investment, natural logarithm	Log Foreign Direct Investment (inwards) as percentage of GDP	World Bank (2014)
Effective Depreciation, natural logarithm	Log Effective Depreciation (labor growth 'n' + depreciation rate 'd'+ growth rate of labor augmenting technology 'A')	World Bank (2014) and EU KLEMS (2014)
Openness, natural logarithm	Log Imports plus exports divided by GDP expressed as a percentage	World Penn Tables (2014)
Government consumption share, natural logarithm	Log Government consumption share of GDP as a percentage	World Bank (2014)
Household consumption share, natural logarithm	Log Households consumption share of GDP as a percentage	World Bank (2014)
OECD dummy	Test whether country part of OECD or not	Dummy Variable
Civil Liberties	Civil liberties measured on a scale from 1-7 with 7 representing highest level of civil liberty.	Freedom House (2014)
Public Rights	Public Rights measured on a scale from 1-7 with 7 representing highest level of rights.	Freedom House (2014)
Freedom Dummy	Countries whose combined average ratings for Public Rights and for Civil Liberties fell between 1.0 and 2.5 were designated "Not Free"; between 3.0 and 5.5 "Partly Free," and between 5.5 and 7.0 "Free." Not free is given a value of 0, Partly free a value of 0.5 and Free is represented by 1 in the dataset.	Freedom House (2014)

The summary (descriptive) statistics are given in table 3.

Table 3 Summary Statistics of the dataset 1996-2010.

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP per capita, logarithm	598	10.3	0.84	8.09	11.6
ICT, logarithm	600	4.02	1.64	-3.65	5.61
Investment share, logarithm	600	-1.51	0.27	-2.98	-0.75
Justice Confidence, Logarithm	600	1.10	0.48	0.01	2.11
Tertiary Education, Logarithm	600	-0.81	0.49	-2.51	-0.05
Effective Depreciation, logarithm	600	-2.52	0.24	-2.94	-1.84
Openness, logarithm	600	-0.04	0.49	-1.27	1.18
OECD Dummy	600	0.58	0.49	0.00	1.00
Govt share, logarithm	600	-2.57	0.32	-3.33	-1.53
Household share, logarithm	600	-0.34	0.18	-0.89	-0.11
FDI, logarithm	600	-3.21	1.10	-7.96	1.46
Civil liberties, logarithm	600	1.77	0.24	1.10	1.95
Public rights, logarithm	600	0.38	0.59	0.00	1.79
Freedom	600	0.87	0.25	0.00	1.00

5. RESULTS

The correlation matrix in non-logarithmic form is given in table 4. Using confidence in justice system as an instrument, including the control variables, the IV 2sls regression results are exhibited in table 5. Looking at Table 5, it is seen that for the OLS regression, ICT is positively correlated to GDP per capita; however when we use the instrument confidence in justice system, the impact is stronger. With the addition of control variables in a step wise manner, the effect of ICT on GDP per capita increases in the IV 2SLS regression.

The F-statistics for the IV 2SLS regression are greater than 10 in all cases, and has a value of 88.08 in specification 5. This means that the instrument for ICT is very strong for each regression specification. Although the level of statistical significance for tertiary education share and openness varies across the specifications, ICT and investment share are significant in all cases. As expected tertiary education share is positively and significantly related to GDP per capita specification 5.

The complete regression specification suggests that ICT increases one percent, then GDP per capita increases by 0.408 percent in specification 5 and 0.148 percent in the OLS regression. It increases from specification 1 till 5 as more control variables are added. Although openness has a negative effect on GDP per capita in specification 3 , it is insignificant in specification 5, therefore with my result I cannot reaffirm Rigobon & Rodrik's (2005) finding that openness negatively impacts GDP per capita.

Civil liberties and freedom are also significantly and positively correlated to GDP per capita. A unit increase on the civil liberty index will increase GDP per workers by 0.684, whereas a unit increase in Freedom increases GDP per worker by 0.652. The positive sign on OECD dummy shows that OECD countries on average will have higher GDP per capita. Government consumption share has a negative impact on GDP per capita, which resonates with Barro's (2000) findings.

FDI is also positively impacts GDP per capita, however a 1 percent increase in FDI yields only a 0.06 percent increase in GDP per capita, which resonates with Lucidi's (2014) finding. Similarly, a percentage increase in household share increase GDP per capita by 0.327 percent in specification

Table 4 Correlation Matrix in Non-Logarithmic Form.

	(1)GDP	(2)ICT	(3)Inv	(4)Tert	(5)Depr	(6)Open	(7)OECD	(8)Gov	(9)House	(10)FDI	(11)Civ	(12)Pub	(13)Fred
(1) GDP per capita	1.000	0.525	0.360	0.462	-0.408	0.290	0.416	-0.087	0.351	0.036	0.610	0.562	0.534
(2) ICT		1.000	0.300	0.613	-0.270	0.315	0.227	-0.138	-0.152	0.064	-0.436	-0.303	0.287
(3) Investment Share			1.000	0.207	-0.160	0.223	0.273	-0.201	-0.066	0.064	-0.272	-0.230	0.153
(4) Tertiary Education				1.000	-0.323	0.139	0.433	-0.279	-0.262	-0.102	-0.470	-0.422	0.418
(5) Effective Depreciation					1.000	0.052	-0.517	0.193	0.246	0.078	0.582	0.672	-0.584
(6) Openness						1.000	-0.106	0.170	0.109	0.034	-0.094	-0.112	0.085
(7) OECD Dummy							1.000	-0.527	-0.548	0.001	-0.655	-0.675	0.619
(8) Govt. Share								1.000	0.362	-0.052	0.316	0.226	-0.193
(9) Household Share									1.000	-0.102	0.525	0.433	-0.433
(10) FDI										1.000	-0.015	0.026	-0.016
(11) Civil Liberties											1.000	0.881	-0.865
(12) Public Rights												1.000	-0.907
(13) Freedom													1.000

Table 5 Regression Results.

Dependent variable: **GDP per worker, logarithm**	**OLS** **(1)**	**IV** **(2)**	**IV** **(3)**	**IV** **(4)**	**IV** **(5)**
ICT, logarithm	0.121*** (6.99)	0.239*** (9.77)	0.428*** (13.53)	0.415*** (12.47)	0.408*** (12.55)
Investment share, logarithm	0.73*** (8.41)	0.107*** (4.30)	0.424*** (3.76)	0.519*** (4.64)	0.509*** (4.94)
Tertiary education share, logarithm	0.189*** (3.37)	0.074 (1.02)	0.449 (0.76)	0.049 (0.67)	0.031 (-0.42)
Effective depreciation, logarithm	-0.468*** (-4.24)	-0.650*** (-4.25)	-0.338** (-2.16)	-0.339** (-2.33)	-0.002 (0.02)
Openness, logarithm	0.072 (1.59)	0.187*** (3.77)	-0.093* (1.81)	0.077 (1.47)	-0.032 (-0.72)
OECD dummy	0.148** (2.14)	0.426*** (5.89)	0.484*** (5.87)	0.378*** (5.10)	0.105 (1.41)
Household share, logarithm	0.537*** (6.72)	-	0.382*** (4.15)	0.469*** (4.80)	0.327*** (3.36)
Government share, logarithm	-0.707*** (-4.90)	-	-	-0.605*** (-3.16)	-0.37** (-2.21)
Foreign direct investment, logarithm	0.018 (1.02)	-	-	0.073* (1.98)	0.06*** (2.77)
Civil Liberties	0.140*** (3.35)	-	-	-	0.684*** (2.42)
Public rights	0.049 (1.16)	-	-	-	0.031 (0.29)
Freedom	0.789*** (3.80)	-	-	-	0.652*** (14.58)
Constant	10.45*** (25.07)	8.281*** (20.02)	8.878*** (18.66)	9.022*** (19.46)	7.855*** (14.58)
F-statistic first stage	-	175.3	118.5	95.01	88.08
R-squared	0.539	0.567	0.589	0.607	0.663
Number of observations	598	598	598	598	598

Note: t-statistics based on robust standard errors are reported in parentheses. *, ** and *** denote statistical significance at the 10-, 5- and 1 percentage level, respectively.

6. CONCLUSION AND SUGGESTIONS FOR FUTURE RESEARCH

The aim of the study was to test the hypothesis, whether ICT has an impact on real GDP per worker in a country. Several studies have been conducted previously; however the true impact of ICT on GDP per capita is yet to be measured. Basing the definition on ICT as the sum of mobile, fixed broadband and internet subscribers per 100 people, I sought out to understand the relationship between the two variables. A simple OLS regression was not sufficient; therefore I used an IV 2sls regression to test the hypothesis.

Since ICT is the endogenous variable, the challenging task was to find at least one strong instrument for the empirical analysis. The instrument I used was the Justice Confidence in the System, taken from the EVS (European Value Survey) between the time periods 1996-2010 for 41 countries. The instrument suffers from endogeneity and impacts GDP per capita through channels other than ICT, therefore I control for these them explicitly by including a number of control variables. The F-tests confirm that the instrument is strong and is valid for my analysis. Finally, the final regression specification shows that ICT has a significant and positive impact on GDP per capita. It is also observed that civil liberties and freedom also positively and significantly impact GDP per capita.

Looking at the results, it is evident that GDP per capita and ICT have a strong positive relationship and an elasticity of 0.408. This is in contrast to Dewan & Kramer (2000), Stiroh (2002) and Loveman's (1994) research which finds a negative relationship between the two variables. Furthermore, the elasticity is not as high as stated by Rasiah (2006), who find it to be at 0.83. Finally, our finding also challenges the weak significant relationship observed by Black & Lynch (2001) and Gilchrist (2001) who find the elasticity to be 0.05 and 0.021 respectively.

Therefore, a country's policy should encourage ICT in general; This encompasses 3G, 4G (and possibly 5G in the next years) licenses, agreements to increase consumer surplus (e.g. avoiding data throttling) and to ensure that a monopoly within a market does not exist (e.g. AT&T and Deutsche Telekom merger which was rejected by the U.S. department of Justice) (Carol 2011). This may include subsidies or regulations (e.g. removing roaming charges across Europe), which make the use and adoption of ICT services easier. It is also seen that the social return from ICT higher than private return, and since this is the case, they must be considered as well. A complete policy would therefore include both of them to gain best results.

Additionally, looking at the results from a business development perspective, the ideal country would therefore be where civil liberties and freedom (political and economic) are respected as they also have a positive impact on productivity.

Finally, there is room for more research on this topic. My dataset includes civil law countries; however this may be expanded to common law countries, subject to the availability of data similar to that extracted from EVS. Moreover, additional control variables may be added in such a case, such as judicial reforms in post war countries, and time specific shocks such as military coups or political turmoil. This would provide an even deeper understanding on the role of judiciary in determining the impact of ICT on GDP per capita.

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